Asymmetric Stability Margin of Postural Response to Perturbation in Unilateral Transtibial Amputees

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Introduction

Higher falling rate in L/E amputation population

- Among community living people with lower extremity amputation (average age 62±15.7y/o), 52% have fallen in the past 12 months. [Miller 2001]

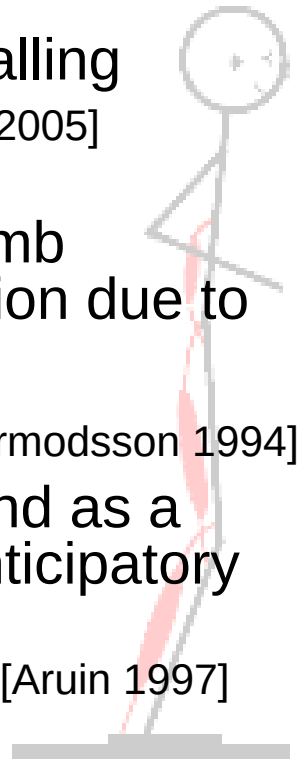
- Only 30% in 65y/o community living elderly have falling experience in the past 12 months. [Gill 2005]

- Posture sway increases in individuals with lower limb amputation in static stance, especially for amputation due to vascular reason.

  [Fernie 1978, Aruin 1997,Isakov 1992, Hermodsson 1994]

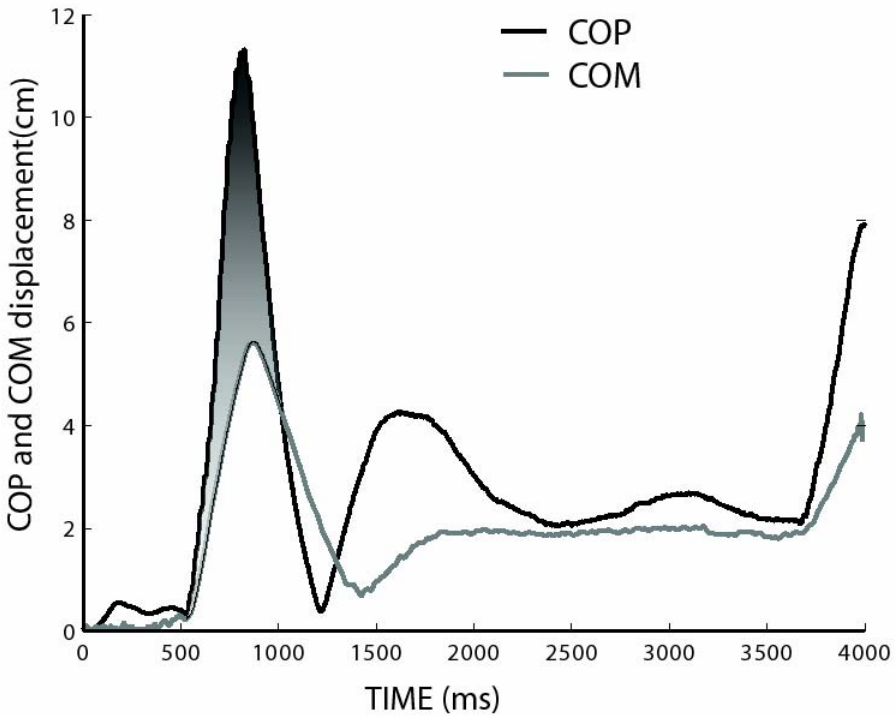
- Asymmetric reaction and EMG response were found as a result of quick arm raise (self elicit perturbation, anticipatory posture perturbation).

  [Aruin 1997]



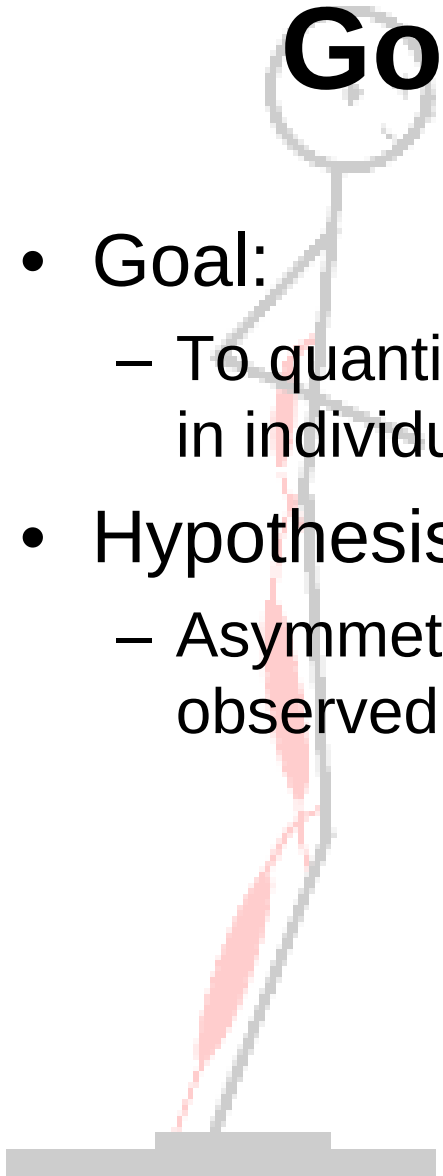
Introduction

Peak CoP-Peak CoM =Stability margin



- Center of pressure (CoP) is the location of the net reactive force at the surface. [Horak 1996]
- Center of mass (CoM) is the balance point of an object's mass.
- To restore a falling body to stable equilibrium, the CoP must move in front of the falling CoM to return the CoM within the Base of Support. [Winter 1990]
- Functional stability margin: the difference between the peak CoP and peak CoM. [Winter 1996]

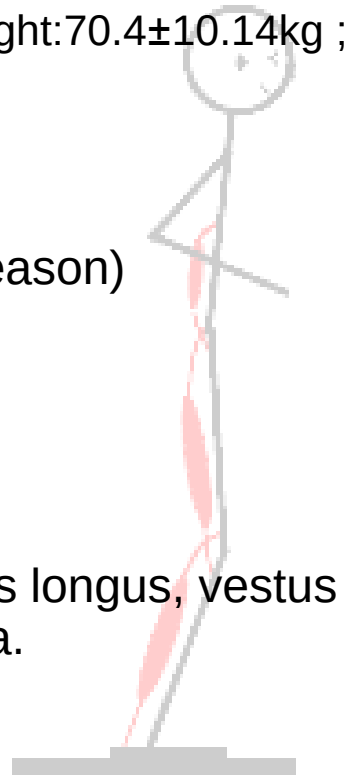
Goal and Hypothesis



- Goal:
  - To quantify directional instability in postural control in individuals with unilateral transtibial amputation.
- Hypothesis:
  - Asymmetric shape of the stability margin can be observed in the amputee group.

Method

- Two subject groups:
  - Control group: 3 subjects (mean height:172±10.2cm; weight:71.9±8.5kg; age:27y/o)
  - Amputee group: 3 subjects (mean height:177±7.2cm; weight:70.4±10.14kg ; age: 27y/o)
    - Included criteria:
      - » 21~40 y/o
      - » unilateral transtibial amputees (traumatic reason)
      - » Full day wearer (>8 hrs)
      - » ABC score >62%
- **Instruments:**
  - Vicon 612 motion capture system
  - EMG: placed on tibialis anterior, medial gastra, peroneous longus, vestus medialis, rectus femoris, biceps femoris, tensor fasica lata.
  - Two AMTI OR6-6 force-plates.



Activity-Specific Balance Confidence (ABC) Scale

Table 3.
Mean Item Activities-Specific Balance Confidence (ABC) Scale Scores for Total Sample and for Respondents With Amputations Due to Vascular and Nonvascular Causes

Item	Total Sample (N=435) $\bar{X}$	SD	Vascular Amputations (n=230)	Nonvascular Amputations[a] (n=205)
4. Reach at eye level	86.2	24.9	80.6	92.5
9. Get in/out of car	83.9	24.3	79.4	88.9
1. Walk around house	81.7	25.5	76.5	87.5
8. Walk outside to nearby car	81.6	26.6	75.3	88.7
3. Pick up slipper from floor	75.9	31.7	68.1	84.7
10. Walk across parking lot	74.2	32.5	65.7	83.8
7. Sweep the floor	69.9	37.3	56.6	84.9
2. Up and down stairs	69.3	32.5	62.9	76.4
12. Walk in crowded mall	63.6	36.8	52.1	76.6
11. Up and down ramp	62.0	34.1	53.4	71.6
14. Escalator holding rail	60.1	40.4	47.9	73.8
13. Walk in crowd/bumped	55.7	37.4	42.3	70.7
5. Reach on toes	50.7	40.9	37.3	65.6
6. Stand on chair to reach	39.1	40.3	22.4	57.5
15. Escalator not holding rail	38.6	39.8	24.9	54.0
16. Walk on icy sidewalks	28.9	32.4	20.6	38.3
Total ABC Scale score	63.8	26.7	54.1	74.7

[a] Difference in means between respondents with amputations due to vascular and nonvascular causes, $P < .001$.

[Powell 1995]

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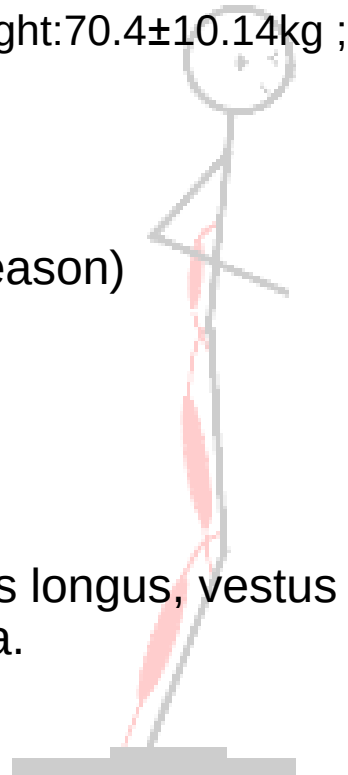
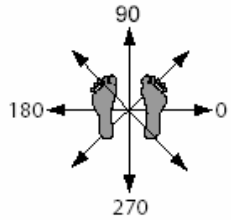
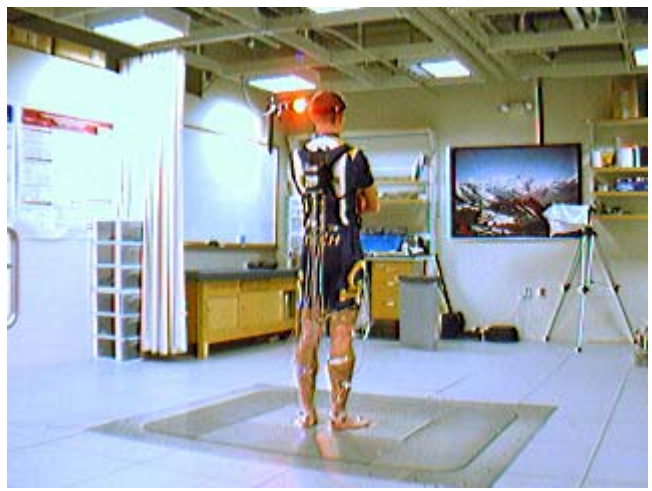


Method

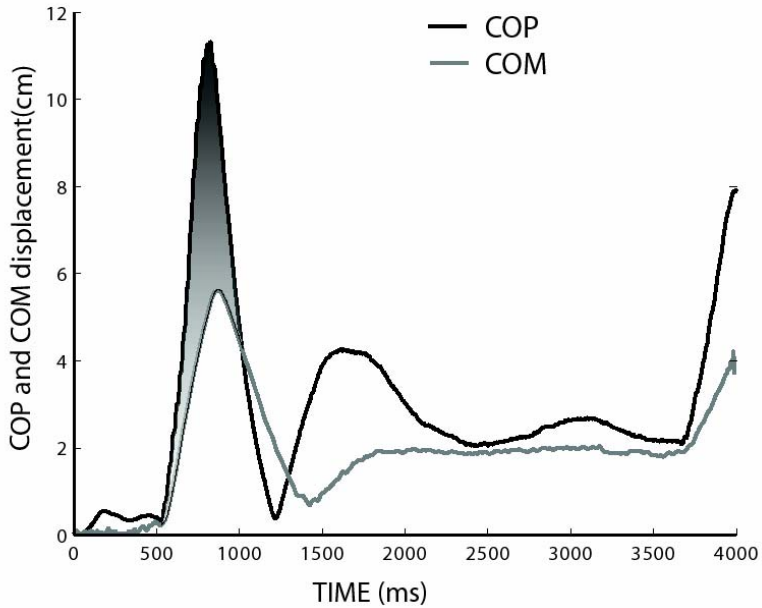


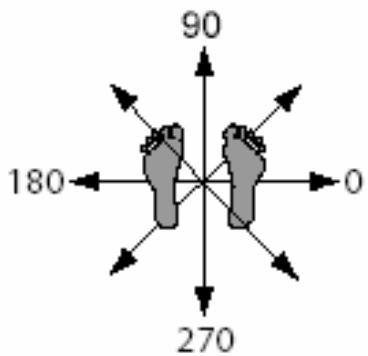
- **Protocol:**
  - Subjects were instructed to stand on each of the force plates with arms folded in front of the chest. 8 randomized directional perturbations (0º,45º,90º,135º,180º,225º,270º,315º) were performed.
  - Subjects were instructed to maintained their balance without moving the feet.
- Kinematic, kinetic and EMG data were recorded.
- CoP, CoM trajectories were calculated from kinematic and kinetic data.



Method

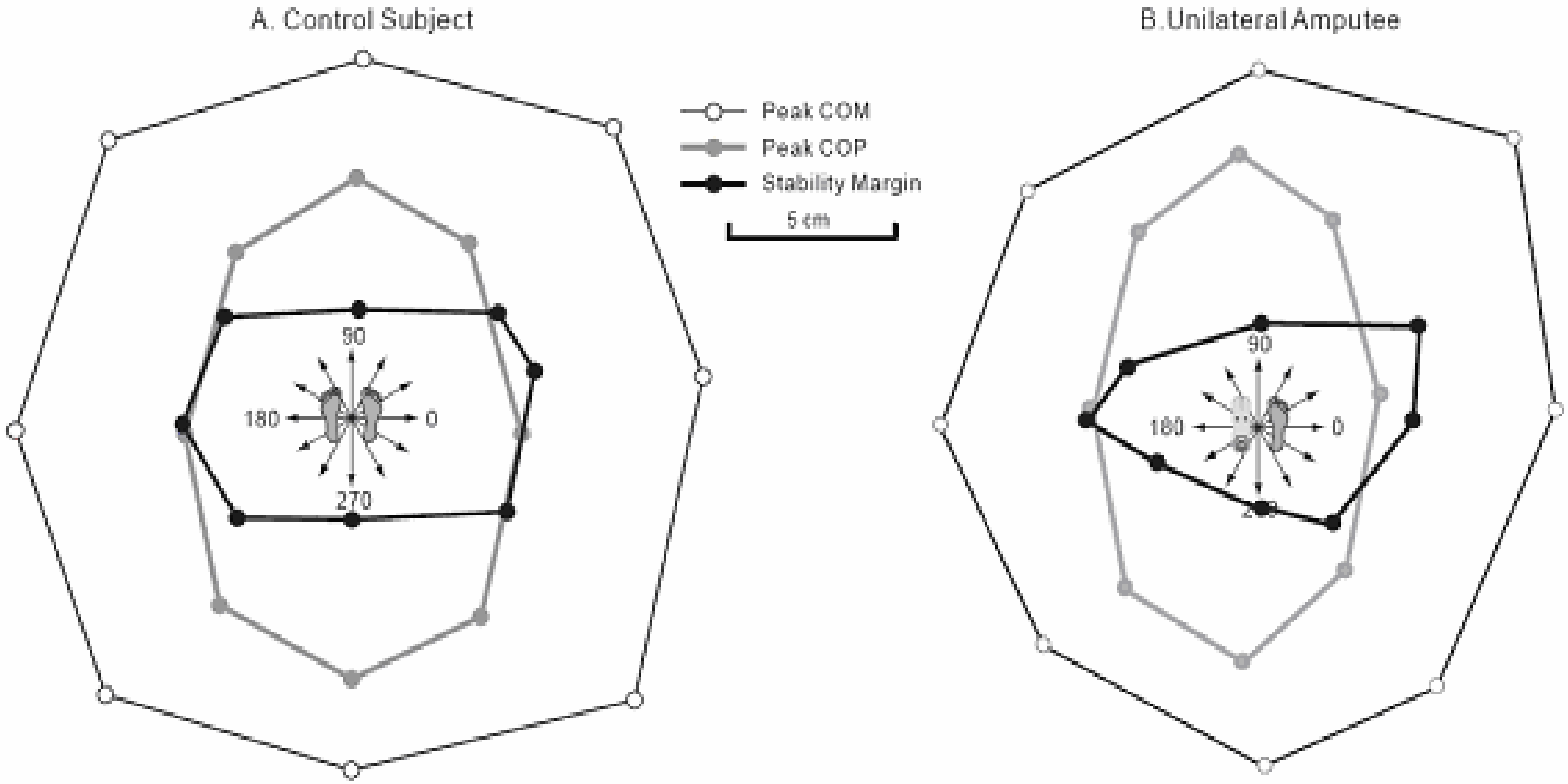
- For each subject, we found the average peak CoP and CoM for each perturbation direction.
- Stability margin of each subject was computed as the difference between peak CoP and CoM.
- Data from right side amputees was reflected, so that the left side could be considered as the amputated side.
- T-test used to compared between groups.





Result

Asymmetric stability margin in amputee group

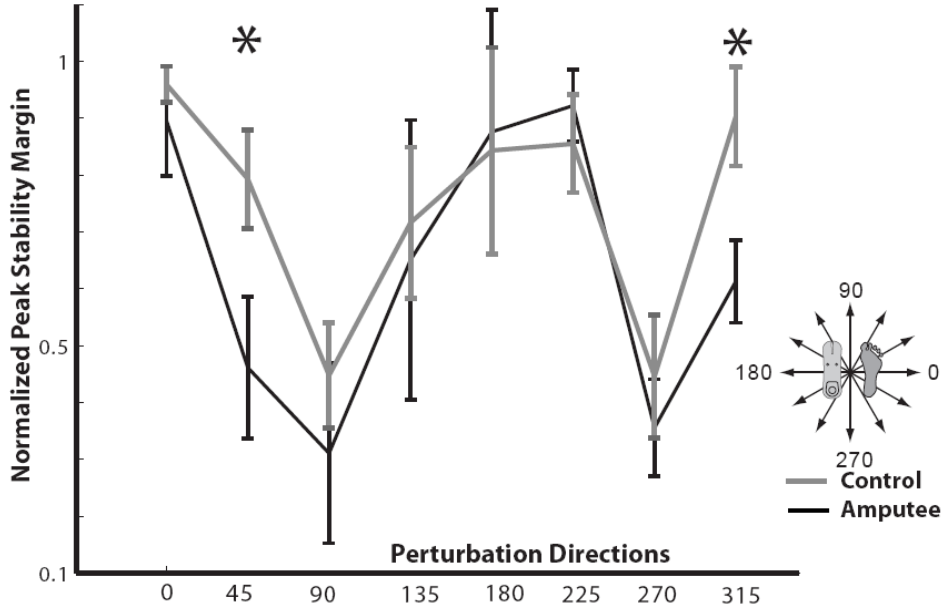


- The stability margin of the control group is symmetric and round.
- The stability margin of amputee group is asymmetrical.

Result

Sig. difference in diagonal directions in amputated side

- There is no significant difference between either AP or ML directions of perturbations between groups
- Stability margin presents significant differences in diagonal directions of amputated sides.



Discussion

- Young and athletic subjects with more equal weight bearing and without fear of weight shifting may result in no significant finding in ML directions.

- Three possible reasons may lead to deficits in posture response in individuals with unilateral transtibial amputation:
  - Sensory :Poor somatosensory score is related to increasing posture sway in static stance. [Quai 2005]
  - Motor: sig. difference in muscle strength between sound side and amputated side. [Morenfeld 2000, Croisier 2001]
  - Prostheses : ROM (inversion/eversion)?

Conclusion

- Significant asymmetric stability margin is found in diagonal directions of amputated side.
- Clinical application:
  - Prosthetic feet design
  - PT balance training
- Future research:
  - Transfemoral level of amputation
  - How different prosthetic feet design influence balance response ?

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- Lena H. Ting, PhD
- Robert Kistenberg, CP
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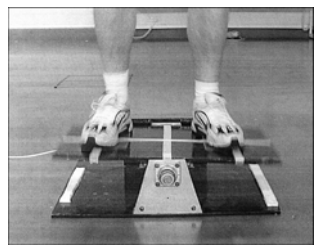
- Hari Trivedi, BS
- All my subjects!!

Introduction

- Anticipatory posture response were be test and found asymmtrical EMG response.
  - Anticipatory disturbance :More asymmetric reaction(larger response on the intact side of body and small or absent on the amputation side).

    Aruin A.S. 1997
  - CoP excursion were significantly greater for amputee group. Longer board contact time (less stable) in TT group in both AP and ML directions. Buckley JG 2002



Result

		Age	Height	Weight
Amputee	**Mean**	27	177.14	70.4433
	Std	7.810	7.240	10.1459
Control	**Mean**	27	172.633	71.967
	Std	2	10.276	8.497
T- Test		1	0.568	0.852

Introduction

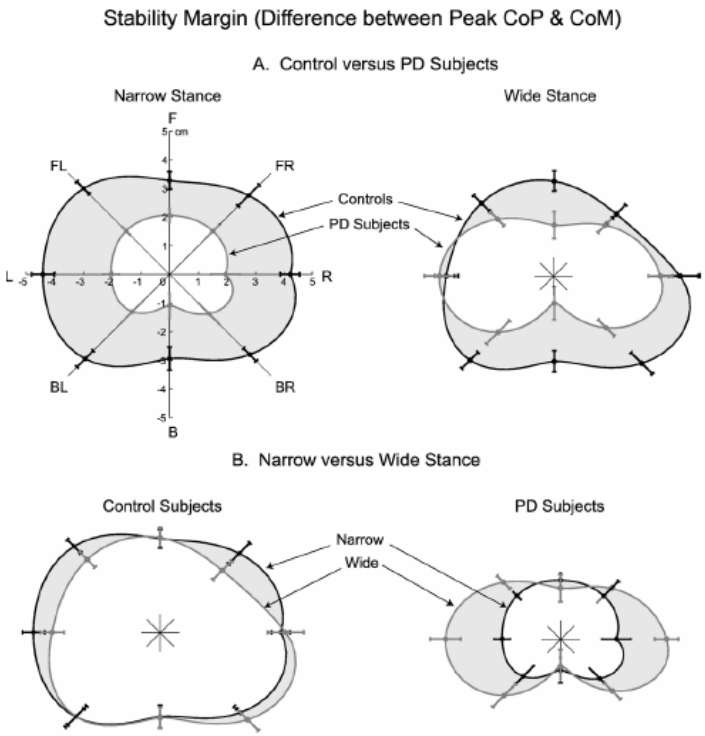


Fig. 7. (A) Comparison of stability margin (difference between peak CoP and peak CoM displacements) in control versus PD subjects in narrow and wide stances over 8 directions of body sway (group mean ± SE). (B) Comparison of stability margin in narrow versus wide stance in control and PD subjects for the data in panel (A). The direction of body sway and the scale at the top left apply to all plots in this figure.